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ABSTRACT

This report describes a real-time simulation experiment to evaluate the performance of the search and editing system 3RIP, an interactive system written in the language BLISS on a DEC-10 computer. The test vehicle, preliminary test runs, and capacity test are detailed, and the following conclusions are reported: (1) 3RIP performs well up to the capacity limit of the DEC-10, (2) long response times could be reduced by solving the problems of how 3RIP files are distributed and how the scheduling algorithm of the operating systems can be altered in order to give jobs creating I/O accesses a low priority, (3) the test vehicle can be a useful tool to find a suitable system design, and (4) the test vehicle can be used to predict system performance under certain circumstances. Appendices include profiles used for the test, a short description of the contents of the databases INSPEC and COMPENDEX, items of CLIST governing the text, and an example of a test run. (FM)

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3RIP EVALUATION OF THE PERFORMANCE OF THE SEARCH SYSTEM USING A REALTIME SIMULATION TECHNIQUE

Mats Löfström

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Abstract

The report describes a real-time simulation experiment to study the performance of the search and editing system 3RIP, implemented on a DEC-10.

In the experiment a user is simulated by a so called pseudoterminal, sending command sequences to 3RIP at a given rate. Each experiment records the overall response time, CPU-time and core memory usage with the number of pseudoterminals, number of records to be searched, command sequences and the time between each command given as exogenous parameters.

When 3RIP is the only system run and the capacity limit of the DEC-10 is not reached (on the particular machine used no more than some 50 users can run concurrently with acceptable response times) the results indicate that 3RIP performs well. The response times are normally less than 2.5 seconds when the number of records searched is not greater than 200 000.

INTRODUCTION

3RIP (1) is an interactive system consisting of two parts: a system for searching textual files and a file handling system with an editor (2). 3RIP is written in the language BLISS (3) on a DEC-10 computer (with a KL 10 processor, 320 K 36-bit words of core memory and four RP 06 disks) at Stockholms Datamaskincentral, QZ. The reentrant part of the search system occupies some 33K words. Each user also needs a minimum of 8 K words of working space.

During the last phase of the development of 3RIP a vehicle for testing the search system has been designed and implemented in order to

- correct errors only detectable when the system is heavily loaded, e.g. when large databases are searched and/or many users are running the system concurrently,
- determine the need for and effects of software changes when optimizing the system,
- determine the capacity of the system, as indicated by the response times and costs associated with a given number of simultaneously active terminals,
- decide if there are important constraints to the DEC-10 timesharing system that seriously affect 3RIP.

This calls for a series of experiments running 3RIP from any number of terminals, the upper limit set by the capacity of the DEC-10. Each experiment should be controlled by input, i.e. number of terminals and the databases to be searched. To be able to decide the effects of system changes, in the 3RIP software or in the DEC-10 configuration, each experiment must also be reproducable.

DESCRIPTION OF THE TEST VEHICLE

For the test a real-time simulation technique was used, where a number of 3RIP programs running on separate terminals were started simultaneously using the DEC-10 system program OPSER (3). Through OPSER a user can initiate up to 13 pseudoterminals, PTYs, from his own terminal. The jobs running on the PTYs are controlled

by OPSER through the passing of both monitor level and system level commands to all or selected jobs. When testing 3RIP a special 3RIP test program simulating the activities of a 3RIP user of the search system is started on each PTY.

When searching a user's time can be said to be spent on:

a) thinking about the next command;

b) typing the command and sending it to 3RIP;

c) waiting until 3RIP responds (RT seconds);

d) waiting until output from 3RIP is finished (TOUT seconds).

These activities can be simulated if the RUN command of 3RIP is slightly modified (4). Normally this command executes a sequence of 3RIP commands specified in a 3RIP record, see appendix A, performing predefined search requests (profiles). The execution of a command sequence can also be repeated any number of times. In the 3RIP test program the routine executing a RUN command is modified in two ways:

- The execution is halted for T seconds after each command in the profile being executed thus, simulating the activities a) and b) above. T is a random number with a probability distribution specified by input to the experiment. The value of T is given by a random number generator (5).

- For each command the routine gathers statistics on response time, costs, number of I/O accesses and core memory needed.

Moreover all terminal output operations from 3RIP are suppressed in the 3RIP test program. This proved necessary as large amounts of text sent to the PTYs are not properly handled by the OPSER program. In the simulation model the suppression of output only causes the time TOUT to be included in T. If the capacity test is used to predict the cost of running 3RIP this fact must be kept in mind, however, since sending text to a terminal is a comparatively costly operation on the DEC-10.

Experimenting with the test vehicle means to initiate a number of PTYs (if more than 13 are needed two or more terminals must be used for the experiment). On all PTYs 3RIP test programs are started and a special

RUN command is given to each program selecting a command sequence and starting its execution. Before starting an experiment the file(s) to be searched are specified. The upper limit of the number of files that can be searched simultanteuosly by 3RIP is 31. This feature has been used to create a large logical file, by specifying that the same physical file should be searched a number of times. Each experiment takes as its input the number N of PTYs and a list CLIST with N items, each item giving the identifier of a command sequence, the number of times the sequence is to be repeated and a specification of the probability distribution of the wait time together with the start values of the random number generator. In all experiments performed a simple uniform probability distribution (MINWT, MAXWT) has been used. To prepare typical command sequences documentalists at the Information and Documentation Centre (IDC) of the Royal Institute of Technology, Stockholm, have used 3RIP for searching a database containing 20 000 INSPEC records (see appendix B). When satisfied with a search a special 3RIP command SAVE has been used to recreate the command sequence that generated the search result and store it in a 3RIP record thus creating a search profile. Eight of these profiles have been used for the test together with two profiles repeating OR and AND operations on large sets. All profiles are listed in appendix A.

For a test run example see appendix D.

PRELIMINARY TEST RUNS

During the first set of test runs 13 profiles were used (see appendix C) all searching 10 files, each file containing the same 20 000 INSPEC records. After debugging 3RIP and the test program a few observations with regard to the test vehicle were made.

1. Each experiment proved expensive to run, implying that the number of experiments has to be kept low. Thus it is not possible to perform a proper statistical analysis on the results. This is no serious drawback, however, since only general observations about system performance are made from the test results. If the test vehicle were to be used for system design then several experiments using different start values for the random number generator would perhaps be needed in order to get useful results.

2. For reasons of time and cost, we wanted to keep the time needed to run each experiment short, i.e. to set MINWT and MAXWT as low as possible. A number of test

runs showed that satisfactory results could be obtained when the values were set to 5 and 15 seconds, respectively. This fact must be remembered when the capacity test are evaluated, as the simulated users are generating commands at a much higher rate and speed than do real users.

3. Due to the DEC-10 timesharing system, the performance of 3RIP is seriously affected by the activities of other DEC-10 users. The performance of the DEC-10 severely deteriorates when large resource consuming programs enter the system or when many terminals are active (at present a serious deterioration of the performance of the DEC-10 at QZ can be noticed when more than 50 to 60 terminals are attached to the system). This means that when comparative tests are made the 3RIP test program must run alone on the DEC-10.

The preliminary test runs also confirmed the strong dependence between the number of I/O accesses needed to execute a command and the response time. Despite the fact that 3RIP was designed to minimize I/O accesses by using a hashing technique and a special data structure for the inverted file, the number of accesses is large because of the need to store intermediary results on disk when large result sets are created. The following example (a database consisting of 10 x 20 000 INSPEC records is searched) gives an example of the problems involved. The commands are taken form the profile P1394.

```
NEUTRON OR NEUTRONS OR GAMMA OR ALPHA
Set no = 1, 13430 occurences in 8070 records

1 OR MUON
Set no = 2, 14000 occurences

PROTON OR PROTONS OR ION OR IONS OR 2
Set no = 3, 28730 occurences in 16470 records
```

The resulting sets require some 10 K, 10 K and 20 K words of storage respectively. Due to the limited amount of core (no more than 70 K words may be used by any program), this implies that it is not possible to save the result sets in core. They are therefore written onto a file (called CONTROL) from which they are read when needed. It would of course have been possible to save smaller sets in core in order to decrease accesses to this control file. This method was rejected, however, as it would make the algorithms unduly complex.

The I/O accesses are divided betseen the control file and the inverted file(s). During the test runs these

files were normally stored on separate disks. As an experiment they were stored on the same disk, which resulted in a marked deterioration of the performance of 3RIP with increased response times. This confirms the obvious observation that if large files are to be searched by 3RIP and thus accessed frequently it would be advantegeous to divide the inverted files and store them on separate disks. As 3RIP can search several files as a logical unit this can be done without difficulty. Division of files implies that more I/O accesses are needed to execute a search command for the same total file size, however. This is clearly shown from the experiments shown in table 1 (all files are stored on the same disk):

1. 5 x 20 000 INSPEC records

   CPU-time: 72 sec RT: 1580 sec
   I/O-accesses: 18400

2. 2 x 50 000 INSPEC records

   CPU-time: 88 sec RT: 330 sec
   I/O-accesses: 11050

Table 1. Comparison between system performance when a file of 100 000 INSPEC records is divided. Both experiments were run with 13 PTYs. The result given is the sum of the total CPU-time, RT and I/O-accesses from the profiles P1394, P1415, P1425, P1439, and P1455.

Thus it appears that the performance of 3RIP may be improved by a carefully designed physical and logical distribution of files of a given 3RIP system.

CAPACITY TEST

To test the capacity of 3RIP experiments were run with 13, 26, and 39 PTYs, all searching two files containing 50 000 INSPEC and 40 000 COMPENDEX records respectively, and with CLIST as in appendix C. In a first attempt to run 39 PTYs the number of files opened by the 3RIP programs (at least five files are needed for each program) exceeded the number of files that could be handled by the DEC-10 operating system. After the creation of a new monitor the experiments could by run. Moreover because of the rapidly growing total size of the control files, the large result sets of certain commands in the profiles P1394 and P1455C caused overflow on the disk used for the control file, which stopped the execution of these profiles. Therefore the results include only eight different profiles.

The experiments showed that the cost and CPU-time were not affected by the number of PTYs run. The response times, however, varied as shown in table 2.

50 000 INSPEC + 40 000 COMPENDEX

No of profiles	Group	Response time Average	Maximum	Minimum
13	1	1.2	9.4	0.16
26	1	2.3	10	0.24
39	1	5.6	32	0.24
13	2	5.4	30	0.92
26	2	7.4	24	1.4
39	2	23	125	1.3

Table 2. Average, maximum, minimum value of response times (in seconds) from 3RIP for 13, 26, and 39 PTYs. The commands have been divided into two groups:

1. With the number of I/O accesses less than or equal to 40.

2. The rest of the commands.

Group 1 contains 133 and group 2 contains 92 commands.

From the data structure and access mechanisms used in 3RIP it is seen that almost all commands, expect composite commands containing OR operations, fall into group 1 when the file size is less than some 200 000 records. The results seem to indicate that all these commands have an acceptable response time for 13 and 26 PTYs. The relatively long response times of the group 2 commands are due to the waiting time for I/O requests to be serviced. When evaluating the results for 39 PTYs it should be noted that 14 monitor programs together with the three OPSER programs are using DEC-10 together with the PTYs. This means that 56 programs are running during the experiment wich is close to the capacity limit of the DEC-10 timesharing system at QZ. The long response times when running 39 PTYs strongly suggests that the upper limit of users that can get acceptable response times from 3RIP is not much lower than what the DEC-10 can handle in its normal operation.

As a final capacity test a large database containing 450 000 records divided between 10 files was searched. Due to the limited amount of disk space and the very large control files generated for this database only six

profiles could be run. The results are shown in table 3.

5 x 50 000 INSPEC + 5 x 40 000 COMPENDEX

Response time:	Average	Maximum	Minimum
	5.9	47	0.34

Table 3. Response times (in seconds) from 3RIP. The profiles run were P1415, P1425, P1439, P1555, and P1455.

The results show that although response times are long due to the number of I/O requests, 3RIP can handle many files of this size.

CONCLUSIONS

The test runs show the performance of 3RIP, when the system is loaded much more heavily than it would be in its normal interactive mode, as

- the commands are sent at a very high rate,
- many of the commands are composite and contain OR operations on large sets, i.e. they create many I/O accesses, which in an interactive mode would cause delays inducing the user to modify his search strategy.

Despite this fact the results from the test appear to show that 3RIP performs well up to the capacity limit of the DEC-10, i.e. 40-50 users may run the system concurrently and get acceptable response times with files containing a total of some 200 000 records. With more users or larger files the total number of I/O operations can be expected to increase and lengthen the response times for resource consuming commands in paritcular.

The long response times could be reduced by a DEC-10 dedicated to 3RIP applications, with reasonable solutions to the following problems:

1. Of how to distribute the files of 3RIP. How many separate disks should be used and how should the inverted and the control files be allocated in order to minimize the overall service time for I/O requests? There is of course a tradeoff between the cost for disk drives and control units and the improvement in system performance.
2. Of how the scheduling algorithm of the operating system should be altered in order to give jobs creating

many I/O accesses a low priority? This would mean very long response times for composite commands and much lower for the rest of the users. This would probably make users split commands and thus the overall performance of 3RIP would be enhanced.

The test has also shown that the test vehicle can be a useful tool both to find a suitable system design i.e. an appropriate file distribution and hardware configuration, and to predict system performance under given circumstances, i.e. when the file size and transaction frequency can be estimated for a given appplication.

References:

(1) Larsson R. et.al. 3RIP: An Interactive Search and Editing System for Large Textual Databases. TRITA-LIB 4042, March 1975.

(2) Löfström M. et.al. 3RIP: Data Structures for Text Files. TRITA-LIB 4061, June 1977.

(3) DEC-System-10. Operating system Commands Manual.

(4) Larsson R. et.al. 3RIP: A User's Manual. March 1979.

(5) Lewis T. General Feedback Shift Register Pseudorandom Number Algorithm. JACM, Vol. 20, July 1973, pp 456-468.

APPENDIX A. The profiles used for the test

```
RECORD: ANDOP     FILE: MARIE.DAT
FIELD: 2
-SF:1-    NEUTRON AND PF='UP_76_02_20'
-SF:2-    NEUTRON AND PF='UP_76_02_20'
-SF:3-    NEUTRON AND PF='UP_76_02_20'
-SF:4-    NEUTRON AND PF='UP_76_02_20'
-SF:5-    NEUTRON AND PF='UP_76_02_20'
-SF:6-    NEUTRON AND PF='UP_76_02_20'
-SF:7-    NEUTRON AND PF='UP_76_02_20'
-SF:8-    NEUTRON AND PF='UP_76_02_20'
-SF:9-    NEUTRON AND PF='UP_76_02_20'
-SF:10-   NEUTRON AND PF='UP_76_02_20'

RECORD: OROP      FILE: MARIE.DAT
FIELD:2
-SF:1-    NEUTRON AND PF='UP_76_02_20'
-SF:2-    NEUTRON OR PF='UP_76_02_20'
-SF:3-    NEUTRON OR PF='UP_76_02_20'
-SF:4-    NEUTRON OR PF='UP_76_02_20'
-SF:5-    NEUTRON OR PF='UP_76_02_20'
-SF:6-    NEUTRON OR PF='UP_76_02_20'
-SF:7-    NEUTRON OR PF='UP_76_02_20'
-SF:8-    NEUTRON OR PF='UP_76_02_20'
-SF:9-    NEUTRON OR PF='UP_76_02_20'
-SF:10-   NEUTRON OR PF='UP_76_02_20'
```

```
RECORD: P1394        FILE: MARIE.DAT
FIELD: 2
-SF:1-  RADIATIONS OR RADIATION_INDUCED OR RADIATION
-SF:2-  COSMIC W1 RAY OR COSMIC W1 RAYS
-SF:3-  SEMICONDUCTOR_DETECTOR OR SEMICONDUCTORS OR SEMICONDUCTOR
-SF:4-  GAMMA_RADIATION OR X_RADIATION OR RADIATIONS OR RADIATION_INDUCED
-SF:5-  4 OR RADIATION
-SF:6-  NEUTRON OR NEUTRONS OR GAMMA OR ALPHA
-SF:7-  6 OR MUON
-SF:8-  DEFECT OR DEFECTS
-SF:9-  DEFECT# NAMES LASTSET
-SF:10- DE=SEMICONDUCTOR_DEFECTS OR SEMICONDUCTOR W1 DEFECT#
-SF:11- 9 AND ( 1 OR 2 )
-SF:12- DAMAGE_ENERGY OR DAMAGES OR DAMGED OR DAMAGE
-SF:13- DAMAGE# NAMES LASTSET
-SF:14- 5 W1 DAMAGE#
-SF:15- 12 EXCEPT 10
-SF:16- 3 AND 13
-SF:17- PROTONS CR PROTON OR IONS OR ION OR 7
-SF:18- ( 8 OR 11) AND 3 AND 15
-SF:19- 16 EXCEPT 14
-SF:20- DE=ELECTRON_HOLE_DROPS OR DE=ELECTRON_HOLE_RECOMBINATION
-SF:21- DE=#ELECTRON_HOLE# NAMES LASTSET
-SF:22- ELECTRON W1 HOLE OR DE=#ELECTRON_HOLE#
-SF:23- 19 AND 3 AND 15
-SF:24- 20 EXCEPT ( 14 OR 17 )
-SF:25- KILL_SET 1 TO 400
```

```
RECORD: P1415          FILE: MARIE.DAT
FIELD: 2
-SF:1-  MANUFACTURED OR MANUFACTURE OR MANUFACTURING
-SF:2-  MANUFACT# NAMES LASTSET
-SF:3-  COMPUTER W1 AIDED AND MANUFACT#
-SF:4-  FORM TRIAL
-SF:5-  PRINT L , 1
-SF:6-  DE=COMPUTER_AIDED_LOGIC_DESIGN OR DE=COMPUTER_AIDED_CIRCUIT_DESIGN OR DE
        =COMPUTER_AIDED_INSTRUCTION OR DE=COMPUTER_AIDED_CIRCUIT_ANALYSIS
-SF:7-  DE=COMPUTER_AIDED_ANALYSIS OR DE=COMPUTER_AIDED_DESIGN OR 3
-SF:8-  DE=DESIGN_AIDS OR DE=DESIGN_ENGINEERING
-SF:9-  DE=DESIGN# NAMES LASTSET
-SF:10- DESIGNERS OR DESIGNER OR DESIGNED OR DESIGNING
-SF:11- 6 OR DESIGN
-SF:12- DESIGN# NAMES LASTSET
-SF:13- DESIGN# OR DE=DESIGN#
-SF:14- DESIGNS OR 8
-SF:15- 2 OR ( 4 and 9 )
-SF:16- PRINT L , 1
-SF:17- KILL_SET 1 TO 400
```

```
RECORD: P1425      FILE: MARIE.DAT
FIELD: 2
-SF:1-  HEALTH OR SAFETY
-SF:2-  HAZARDS OR HAZARD
-SF:3-  HAZARD# NAMES LASTSET
-SF:4-  HUMAN OR HAZARD#
-SF:5-  3 AND ELECTROMAGNETIC
-SF:6-  DE=SAFETY_SYSTEMS OR DE=SAFETY
-SF:7-  DE=#SAFETY# NAMES LASTSET
-SF:8-  FIND DE=HEALTH_HAZARDS
-SF:9-  DE=#HAZARD# NAMES LASTSET
-SF:10- DE=ELECTROMAGNETIC_OSCILLATIONS OR DE=ELECTROMAGNETIC_INTERFERENCE OR DE
        =ELECTROMAGNETIC_WAVES OR DE=ELEMENTARY_PARTICLE_ELECTROMAGNETIC_INTERACTIONS
-SF:11- DE=ELECTROMAGNETIC_FIELDS OR 7
-SF:12- DE=#ELECTROMAGNETI# NAMES LASTSET
-SF:13- DE=#ELECTROMAGNETI# AND ( DE=#HAZARD# OR DE=#SAFETY# OR DE=HEALTH )
-SF:14- ( 3 AND 8 ) OR ( 1 AND 8 ) OR ( 6 AND ELECTROMAGNETIC )
-SF:15- 10 OR 9
-SF:16- AU=JOHNSON_C_R OR AU=JOHNSON_C_A OR AU=JOHNSON_C_E OR AU=JOHNSON_C_C
-SF:17- AU=JOHNSON_C_B OR 12
-SF:18- AU=JOHNSON_C# NAMES LASTSET
-SF:19- FIND AU=KAUFMAN_G_J_JR
-SF:20- AU=KAUFMAN_G# NAMES LASTSET
-SF:21- FIND AU=YAMAURA_K
-SF:22- AU=YAMAURA# NAMES LASTSET
-SF:23- AU=YAMAURA# OR AU=KAUFMAN_G# OR AU=MICHAELSON_S OR AU=JOHNSON_C#
-SF:24- 4 OR 11 OR 16
-SF:25- KILL_SET 1 TO 400
```

```
RECORD: P1439     FILE: MARIE.DAT
FIELD: 2
-SF:1-  JOINTS OR JOINT
-SF:2-  JOINT# NAMES LASTSET
-SF:3-  CABLE W1 LAYING OR CABLE W1 JOINT# OR CABLES
-SF:4-  TELECOMMUNICATIONS OR TELECOMMUNICATION
-SF:5-  TELECOMMUNICATION# NAMES LASTSET
-SF:6-  TELECOMMUNICATION# AND 2
-SF:7-  DE=TELECOMMUNICATION_LINKS OR DE=TELECOMMUNICATION_CABLES
-SF:8-  DE=#TELECOMMUNICAT# NAMES LASTSETS
-SF:9-  DE=SUPERCONDUCTING_CABLES OR DE=SUPERCONDUCTING_CABLES OR DE=CABLE_LAYIN
       G OR DE=CABLE_LAYING
-SF:10- DE=UNDERGROUND_CABLES OR DE=UNDERGROUND_CABLES OR DE=CABLE_SHEATHING OR
       DE=SUBMARINE_CABLES
-SF:11- DE=SUBMARINE_CABLES OR DE=CABLE_JOINTING OR DE=CABLE_JOINTING OR DE=CABL
       ES_ELECTRIC
-SF:12- DE=CABLES_ELECTRIC OR 6 OR DE=CABLE_INSULATION OR DE=CABLE_INSULATION
-SF:13- DE=COAXIAL_CABLES OR DE=POWER_CABLES OR DE=POWER_CABLES OR DE=TELECOMMUN
       ICATION_CABLES
-SF:14- DE=TELECOMMUNICATION_CABLES OR 7 OR 8 OR 9
-SF:15- 10 OR 11
-SF:16- DE=#CABLE#  NAMES LASTSET
-SF:17- DE=#CABLE# AND DE=#TELECOMMUNICAT#
-SF:18- 4 OR 13
-SF:19- EXCHANGE OR EXCHANGER OR EXCHANGES OR EXCHANGE
-SF:20- EXCHANGE#  NAMES LASTSET
-SF:21- TELEPHONE W1 EQUIPMENT OR TELEPHONE W1 EXCHANGE#
-SF:22- 16 EXCEPT 14
-SF:23- DE=TELEPHONE_EQUIPMENT OR DE=TELEPHONE_EXCHANGES OR DE TELEPHONE_SWITCHI
       ING_EQUIPMENT OR DE=TELEPHONE_STATION_EQUIPMENT
```


(CONTINUED)

```
-SF:24- DE=PRIVATE_TELEPHONE_EXCHANGES OR 18
-SF:25- TELECOMMUNICATIONS OR TELECOMMUNICATION
-SF:26- INSTALLATIONS OR INSTALLATION
-SF:27- DE=TELECOMMUNICATION_LINKS OR DE=TELECOMMUNICATION_TRAFFIC OR DE=TELECOM
        MUNICATION OR DE=TELECOMMUNICATION_SYSTEM
-SF:28- DE=TELECOMMUNICATION_EQUIPMENT OR 22 OR DE=TELECOMMUNICATION_CABLES
-SF:29- DE=#TELECOMMUNICATION#  NAMES LASTSET
-SF:30- DE=INSTALLATION OR DE=COMPUTER_INSTALLATION
-SF:31- DE=#INSTALLATION#  NAMES LASTSET
-SF:32- DE=#INSTALLATION# AND DE=#TELECOMMUNICATION#
-SF:33- 23 AND 21 EXCEPT ( 14 OR 17 OR 25 )
-SF:34- ( 24 AND 20 ) EXCEPT ( 14 OR 15 OR 29 OR 26 )
-SF:35- ( 21 OR 24 ) AND ( 18 OR 19 )
-SF:36- 14 OR 17 OR 25 OR 26 OR 27 OR 28
```

```
RECORD: P1455      FILE: MARIE.DAT
FIELD: 2
-SF:1-  MINICOMPUTERS_A OR MINICOMPUTERS OR MINICOMPUTER
-SF:2-  MINICOMPUTER# NAMES LASTSET
-SF:3-  MICROPROCESSORS_THEIR OR MICROPROCESSORS_INTRODUCTION OR MICROPROCESSOR_
        S OR MICROPROCESSORS
-SF:4-  2 OR MICROPROCESSOR
-SF:5-  MICROPROCESSOR# NAMES LASTSET
-SF:6-  MICROCOMPUTER OR MICROCOMPUTERS
-SF:7-  MICROCOMPUTER# NAMES LASTSET
-SF:8-  MICROCOMPUTER# OR MICROPROCESSOR# OR MINICOMPUTER#
-SF:9-  APPLICATION_ANALYSIS OR APPLICATIONS_ A OR APPLICATION OR APPLICATIONS
-SF:10- APPLICATION# NAMES LASTSET
-SF:11- 5 AND APPLICATION#
-SF:12- DE=MICROCOMPUTERS OR DE=MICROPROCESSORS OR DE=MINICOMPUTERS
-SF:13- 6 AND 8
-SF:14- 7 OR 9
-SF:15- DE=COMPUTER_APPLICATIONS OR DE=SPECTROSCOPY_APPLICATIONS_OF_COMPUTERS OR
        DE COMMUNICATIONS_APPLICATIONS_OF_CONTROL OR DE=AEROSPACE_APPLICATIONS_OF_COMPU
        TERS
-SF:16- DE=ELECTRONICS_APPLICATIONS_OF_COMPUTERS OR DE=COMMUNICATIONS_APPLICATIO
        NS_OF_COMPUTERS OR DE=NS_APPLICATIONS_OF_CONTROLCOMPUTERS OR DE=BIOMEDICAL_APPLI
        CATIONS_OF_COMPUTER
-SF:17- 11 OR DE=NATURAL_SCIENCES_APPLICATIONS_OF_COMPUTERS OR DE=ENGINEERING_AP
        PLICATIONS_OF_COMPUTERS OR DE=CONTROL_ENGINEERING_APPLICATIONS_OF_COMPUTERS
-SF:18- DE=PHYSICS_APPLICATIONS_OF_COMPUTERS OR DE=ELECTRICAL_ENGINEERING_APPLIC
        ATIONS_OF_COMPUTERS OR T2 OR 13
-SF:19- ( 5 OR 8 ) AND 14
-SF:20- 15 EXCEPT 10
-SF:21- 15 OR 16
-SF:22- KILL_SET 1 TO 400
```

```
RECORD: P1455C      FILE: MARIE.DATE
FIELD: 2
-SF:1-  MINICOMPUTERS_A OR MINICOMPUTERS OR MINICOMPUTER
-SF:2-  MINICOMPUTER# NAMES LASTSET
-SF:3-  MICROPROCESSORS_THEIR OR MICROPROCESSORS_INTRODUCTION OR MICROPROCESSOR_
        S OR MICROPROCESSORS
-SF:4-  2 OR MICROPROCESSOR
-SF:5-  MICROPROCESSOR#  NAMES LASTSET
-SF:6-  MICROCOMPUTER OR MIKROCOMPUTERS
-SF:7-  MICROCOMPUTER#  NAMES LASTSET
-SF:8-  MICROCOMPUTER#  OR MICROPROCESSOR#  OR MINICOMPUTER#
-SF:9-  APPLICATION_ANALYSIS OR APPLICATIONS_A OR APPLICATION OR APPLICATIONS
-SF:10- APPLICATION#  NAMES LASTSET
-SF:11- 5 AND APPLICATION#
-SF:12- DE=MICROCOMPUTERS OR DE=MICROPROCESSORS OR DE=MINICOMPUTER
-SF:13- 6 AND 8
-SF:14- 7 OR 9
-SF:15- DE=COMPUTER_APPLICATIONS OR DE=CPECTROSCOPY_APPLICATIONS_OF_COMPUTERS OR
        DE=COMMUNICATIONS_APPLICATIONS_OF_CONTROL OR DE=AEROSPACE_APPLICATIONS_OF_COMPU
        TERS
-SF:16- DE=ELECTRONICS_APPLICATIONS_OF_COMPUTERS OR DE=COMMUNICATIONS_APPLICATIO
        NS_OF_COMPUTERS OR DE=NS_APPLICATIONS_OF_CONTROLCOMPUTERS OR DE_BIOMEDICAL_APPLI
        CATIONS_OF_COMPUTERS
-SF:17- 11 OR DE=NATURAL_SCIENCES_APPLICATIONS_OF_COMPUTERS OR DE=ENGINEERING_AP
        LICATIONS_OF_COMPUTERS OR DE=CONTROL_ENGINEERING_APPLICATIONS_OF_COMPUTERS
-SF:18- DE=PHYSICS_APPLICATIONS_OF_COMPUTERS OR DE=ELECTRICAL_ENGINEERING_APPLIC
        ATIONS_OF_COMPUTERS OR 12 OR 13
-SF:19- ( 5 OR 8 ) AND 14
-SF:20- 15 EXCEPT 10
-SF:21- 15 OR 16
-SF:22- FIND DE=MARKETING
-SF:23- ( 5 OR 8 ) AND ( COMPONENT OR COMPONENTS OR DE=COMPONENT )
-SF:24- FIND DE=PERFORMANCE_INDEX
-SF:25- DE=#PERFORMANC# NAMES LASTSET
```


(CONTINUED)

```
-SF:26- ( 5 OR 8 ) AND ( PERFORMANCE OR PERFORMANCES OR DE=#PERFORMANC# )
-SF:27- ( 5 OR 8 ) AND INTEGRATED WI CIRCUIT
-SF:28- DE=MICROWAVE_INTEGRATED_CIRCUITS OR DE=LINEAT_INTEGRATED_CIRCUITS OR DE=
        INTEGRATED_CIRCUIT_TESTING OR DE=INTEGRATED_CIRCUIT
-SF:29- DE=HYBRID_INTEGRATED_CIRCUITS OR DE=DIGITAL_INTEGRATED_CIRCUITS OR DE=IN
        INTEGRATED_CIRCUIT_PRODUCTION OR 23
-SF:30- DE=MONOLITHIC_INTEGRATED_CIRCUITS OR 24
-SF:31- DE=#INTEGRATED_CIRCUIT#  NAMES LASTSET
-SF:32- INTEGRATED WI CIRCUITS OR DE=#INTEGRATED_CIRCUIT#
-SF:33- 22 OR ( ( 5 OR 8 ) AND 26 )
-SF:34- MINICOMPUTER OR MINICOMPUTERS OR DE=MINICOMPUTERS
-SF:35- 27 OR 21 OR 19 OR 18 OR 17
-SF:36- 29 EXCEPT 28
-SF:37- 29 EXCEPT 30
```

```
RECORD: P1459      FILE: MARIE.DAT
FIELD: 2
-SF:1-  RELIABILITY_INDUCTIVE OR RELIABILITY_IMPROVEMENT OR RELIABILITIES OR REL
        IABLE
-SF:2-  1 OR RELIABILITY
-SF:3-  RELIAB#  NAMES LASTSET
-SF:4-  RELIABILITY OR RELIAB#  OR DE=RELIABILITY
-SF:5-  INFORMATION OR DE=INFORMATION
-SF:6-  4 AND 3 AND ( ORGANISATION OR ORGANIZATION OR FEEDBACK )
-SF:7-  FIND DE=FILE_ORGANISATION
-SF:8-  DE=#ORGANISATION#  NAMES LASTSET
-SF:9-  DE=#ORGANISATION#  OR DE=ORGANIZATION
-SF:10- FIND DE=FEEDBACK
-SF:11- 5 OR ( 4 AND 3 AND ( 8 OR 7 ) )
-SF:12- KILL_SET 1 TO 400
```

```
RECORD: P1555      FILE: MARIE.DAT
FIELD: 2
-SF:1-  SENSORS OR SENSOR
-SF:2-  SENSOR#  NAMES LASTSET
-SF:3-  FIND DE=IMAGE_SENSORS
-SF:4-  DE=#SENSOR#  NAMES LASTSET
-SF:5-  ROBOT_MANIPULATORS OR ROBOTS OR ROBOT
-SF:6-  ROBOT#  NAMES LASTSET
-SF:7-  TRANDUCER#  OR TACTILE OR VISUAL OR ROBOT#
-SF:8-  FIND DE=ROBOTS
-SF:9-  DE=#ROBOT#  NAMES LASTSET
-SF:10- FIND DE=TRANSDUCERS
-SF:11- DE=#TRANSDUCER#  NAMES LASTSET
-SF:12- DE=#TRANSDUCER#  OR DE=TACTILE OR DE=VISUAL OR DE=#ROBOT#
-SF:13- ( 7 OR 4 ) AND SENSOR#
-SF:14- ( 7 OR 4 ) AND DE=#SENSOR#
-SF:15- 8 OR 9
-SF:16- FIND DE=PARTICLE_TRACK_VISUALISATION
-SF:17- DE=#VISUAL#  NAMES LASTSET
-SF:18- VISUAL OR DE=#VISUAL#
-SF:19- 12 AND SENSOR#
-SF:20- 12 AND DE=#SENSOR#
-SF:21- 13 OR 14
-SF:22- 15 EXCEPT 10
-SF:23- PROXIMITY OR MATERIALS OR HANDLING OR ARTIFICAL
-SF:24- FIND DE=MATERIALS_HANDLING
-SF:25- DE=#HANDLING#  NAMES LASTSET
-SF:26- DE=MATERIALS OR DE=POROUS_MATERIALS OR DE=GRANUALAR_MATERIALS OR DE=MATER
       IALS_HANDLING
-SF:27- DE=#MATERIALS#  MANES LASTSET
-SF:28- DE=PROCIMITY OR DE=MATERIAL OR DE=#MATERIALS#  OR DE=#HANDLING#  OR DE=ART
       IFICAL
-SF:29- 17 OR 20
-SF:30- 21 OR ( 4 OR 7 )
-SF:31- 22 AND SENSOR# OR 22 AND DE=#SENSOR#
-SF:32- 23 EXCEPT 10
-SF:33- FIND DE=ELECTRIC_SENSING_DEVICES
-SF:34- 25 OR 24 OR 16 OR 10
```

APPENDIX B. A short description or the contents of the databases INSPEC and COMPENDEX

INSPEC

Information service in Physics, Electrotechnology, Computers and Control from the Institution of Electrical Engineers (U.K) in collaboration with the Institute of Electrival and Electronic Engineers (USA). This data base contains yearly about 150 000 references to articles, reports, patents and other litterature in the fields specified in the title. The corresponding printed publication is issued under different titles: Physics Abstracts, Electrical&Electronics Abstracts, and Computer&Control Abstracts.

COMPENDEX

Computerized Engineering Index from Engineering Index Inc. (USA) covers the litterature in engineering and technology and biotechnology as well. Primarily it covers articles and conferences but monograhs, patents and standards are also included. The tapes contain about 90 000 references a year. The corresponding printed publication is called Engineering Index Monthly.

APPENDIX C. The items of CLIST governing the test

ENTRY NO.: 1	PROFILE: P1394	MAX-WT: 10	MIN-WT: 5	REPEAT: 1
ENTRY NO.: 2	PROFILE: P1415	MAX-WT: 10	MIN-WT: 5	REPEAT: 2
ENTRY NO.: 3	PROFILE: P1425	MAX-WT: 10	MIN-WT: 5	REPEAT: 1
ENTRY NO.: 4	PROFILE: P1439	MAX-WT: 10	MIN-WT: 5	REPEAT: 0
ENTRY NO.: 5	PROFILE: P1455	MAX-WT: 10	MIN-WT: 5	REPEAT: 1
ENTRY NO.: 6	PROFILE: P1455C	MAX-WT: 10	MIN-WT: 5	REPEAT: 0
ENTRY NO.: 7	PROFILE: P1459	MAX-WT: 10	MIN-WT: 5	REPEAT: 3
ENTRY NO.: 8	PROFILE: P1555	MAX-WT: 10	MIN-WT: 5	REPEAT: 0
ENTRY NO.: 9	PROFILE: OROP	MAX-WT: 20	MIN-WT: 40	REPEAT: 0
ENTRY NO.: 10	PROFILE: ANDOP	MAX-WT: 20	MIN-WT: 40	REPEAT: 0
ENTRY NO.: 11	PROFILE: P1394	MAX-WT: 10	MIN-WT: 5	REPEAT: 1
ENTRY NO.: 12	PROFILE: P1415	MAX-WT: 10	MIN-WT: 5	REPEAT: 2
ENTRY NO.: 13	PROFILE: P1425	MAX-WT: 10	MIN-WT: 5	REPEAT: 1
ENTRY NO.: 14	PROFILE: P1439	MAX-WT: 10	MIN-WT: 5	REPEAT: 0

APPENDIX D. An example of a test run.

Table 1 shows how OPSER is run with n=2, table 2 the items of CLIST governing this run, table 3 the search result of 3RIP for one of the profiles (normally this is not saved) and table 4 gives the test results for this profile (output from an experiment consists of n such results).

```
.R OPSER                                    START OPSER

*:SLOG                                      INITIATE TWO PTYS
*:SLOG
*ALL-RUN 3RIP                               START 3RIP ON BOTH PTYS
*ALL-TINIT                                  OPEN FILES USED FOR STATISTICAL OUTPUT
*ALL-RUN IKS.T3RIP.DAT                      SELECT AN ARBITRARY ITEM FROM CLIST.
                                            REMOVE THE ITEM AND START EXECUTING
                                            THE COMMAND SEQUENCE OF THE PROFILE
                                            IDENTIFIED BY THE ITEM.

                    COMMAND SEQUENCES ARE EXECUTED

*ALL-TEXIT                                  CLOSE STATISTICAL FILES
*ALL-EXIT                                   EXIT FROM 3RIP
*:KILL ALL                                  KILL THE PTYS AND RETURN TO MONITOR MODE
*:EX
```

Table 1. A 3RIP test run using OPSER. All output from OPSER except the promter (*) has been excluded. After the command RUN 3RIP the program asks for password and in certain 3RIP test programms the number of files to be searched and the version of CLIST are to be entered after the command TINIT. The answers to these questions, wich are also excluded from this listing, are entered through OPSER.

```
ENTRY NO: 1     PROFILE: P1415   MAX-WT:2     MIN-WT:1     REPEAT:0
ENTRY NO: 2     PROFILE: P1459   MAX-WT:2     MIN-WT:1     REPEAT:0
```

Table 2. The items of CLIST governing the test example. The command sequences of the profiles are given in appendix A.

```
RELIABILITY_INDUCTIVE OR RELIABILITY_IMPROVEMENT IR RELIABILITIES OR RELIABLE
Set no = 1,  13 occurrences in 13 records
1 OR RELIABILITY
Set no = 2,  266 occurrences
RELIAB   NAMES LASTSET
RELIABILITY OR RELIAB   OR DE=RELIABILITY
Set no 4 3,  197 occurrences in 197 records
INFORMATION OR DE=INFORMATION
Set no 4 4,  400 occurrences
4 AND 3 AND ( ORGANISATION OR ORGANIZATION OR FEEDBACK )
Set no = 5,  0 occurrences
FIN DE=FILE_ORGANISATION
Set no 4 6,  15 occurences
DE= ORGANISATION   NAMES LASTSET
DE= ORGANISATION   OR DE=ORGANIZATION
Set no = 7,  15 occurences
FIND DE =FEEDBACK
Set no = 8,  43 occurrences
5 OR ( 4 AND 3 AND ( 8 OR 7 ) )
Set no = 9,  0 occurences
KILL_SET 1 TO 400
```

Table 3. The response from 3RIP when the profile P1459 is run.

FCNT: 01 PROF: P1459 FILE: MARIE.DAT
IDNO: 02 MSID: 02 MAX-WT: 002 MIN-WT: 01 REPT: 0
DATE: 78-10-02 TIME: 23:49:58 LS-MEM: 17 HS-MEM: 66 CMDS: 14

CMD	TIME	RTIM	RUN	WAIT	COST	IO(R/W)	LS-MEM	JOBS
000	23:49:58	000,000	000,000	000	00.00	0000/0000	17	28
001	23:50:02	000,240	000,026	002	00.01	0015/0001	18	28
002	23:50:05	001,360	000,092	002	00,06	0021/0020	18	28
003	23:50:09	002,480	000,077	001	00,03	0014/0004	18	28
004	23:50:10	000,000	000,000	001	00,00	0000/0000	18	28
005	23:50:12	001,020	000,153	001	00,04	0018/0004	18	28
006	23:50:16	001,020	000,035	002	00,01	0010/0004	18	28
007	23:50:22	002,740	000,168	002	00,05	0029/0004	18	28
008	23:50:26	000,600	000,018	002	00,01	0007/0007	18	28
009	23:50:27	000,000	000,000	001	00,00	0000/0000	18	28
010	23:50:30	000,480	000,035	002	00,02	0009/0005	18	28
011	23:50:31	000,220	000,025	001	00,01	0004/0004	18	28
012	23:50:36	001,640	000,120	002	00,05	0024/0007	18	28
013	23:50:42	003,400	000,054	002	00,09	0076/0014	18	28
TOT.	00:00:43	015,200	000,803	022	00,38	0227/0074		

TOTAL COST: 00.39

Table 4. The result from the PTY on which P1459 is run. The CMD number 2 gives statistic about the first command of the profile.

TIME: The time when the command was sent to 3RIP.
RTIM: The response time.
RUN: The CPU-time used for the command.
WAIT: The value of the random variable T.
COST: The cost of the command in the experiment.

(continued)

I/O: The number of accesses to blocks of 128 words on secondary memory.
R denotes reading and W writing.
N.B. A 3RIP block consists of 512 words. i.e. to get the number
of I/O requests from 3RIP the value should be divided by four.

LS-MEM: Core memory (number of 500 wnd blocks) occupied by the user program between each command

PROF: The profile identifier.

FCNT: The number of files searched.

REPT: The number of times the profile should be repeated.